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Determination of Mount Merapi Volcanic Earthquake Hypocentre By Using Seismic Wave Polarization Analysis

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Abstract: Volcanic earthquakes of mount Merapi have been investigated periodically. The investigation aims to determine the hypocenter and epicenter of mount Merapi's volcanic earthquake using wave polarization analysis. The analysis was carried out in three domains, which are the time domain, the frequency domain, and the space domain. The analysis in the time domain was conducted by the arrival time of the volcanic earthquake, and the analysis in the frequency domain was done by observing the spectrum to get information on source frequency and bandwidth passed from polarization analysis, while the analysis in the space domain was conducted especially on hypocenter determination of the volcanic earthquakes. The analysis leads to the frequency of source 6 Hz and a bandwidth of 0.1 Hz. Thus, the hypocenter of volcanic earthquakes by polarization analysis was distributed to depth from 670 m to 3250 m from Merapi's top.

Keywords: Hypocenter; mount Merapi; polarization analysis; seismic wave; volcanic earthquake

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Introduction

Mount Merapi slopes spread in the various districts of Magelang, Boyolali, Klaten, and Yogyakarta. Besides being recorded as the most active volcanoes in the world, it also has many physical phenomena that are difficult to observe, such as sound wave symptoms (acoustic) and symptoms of deformation (shape changes) [1]. Apart from these two symptoms, there are still physical quantities correlated with the volcano's internal dynamics, including changes in geomagnetic fields, geoelectric fields, and temperature. Analysis of this massive data is very complex because many external factors influence it.

Based on this, then for modeling, determining volcanic activities' status and forecast often used seismic symptoms and deformation without ignoring other symptoms [2]. Volcanoes are interesting research objects for many researchers. In previous research of Kirbani [3], seismicity studies have been conducted on Krakatau volcano using three directions seismic components. This study concluded that volcanic eruptions are the result of gas flow with a supersonic boom. In Setiawan [4], three-component seismic measurements were taken during the Merapi volcano lava dome formation. This research succeeded in determining the polarization parameters (reverse azimuth and angle of incidence).

Bath [5] has made a general description of the types of volcanic earthquakes. This study pointed out that the spectrum resemblance of a seismic symptom received by two stations can be associated with the

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source's characteristics. Sukrisna [6] states that seismic data 3 broadband components at two stations can determine the volcanic earthquake source position and the average velocity of seismic waves and the eruption's average flow rate fluid on Mount Krakatau. Another aspect is examining the internal condition of volcanoes through seismicity of the earthquake on the volcano. Seismicity produced by volcanic earthquakes from internal processes can be recorded by seismometer equipment on the surface. The results recorded in seismogram data after being processed will give some information [7].

One of the important information is knowing the position of the source of the volcanic earthquake. The volcanic earthquake source position's determination is determined by finding the direction of the wave arrival by measuring the azimuth and angle of return with the method of polarization analysis of particle motion [8]. This research was aimed to determine the position of the Merapi volcanic earthquake hypocenter. A volcanic earthquake position can provide further information about internal conditions.

Method

Data processing in this study was the analysis of seismic waves in 3 regions, namely (1) analysis of the time zone, (2) analysis of the frequency region and, (3) analysis of the spatial region. Analysis of the time zone aims to determine the volcanic earthquake's arrival time at each seismometer [9].

The arrival time is determined according to the direction components at each station so that the reception order is obtained. Analysis of the frequency region was carried out to determine the frequency content of the volcanic earthquake symptoms. These analyses regions need to be done to analyze the ascertained symptoms of the volcanic earthquake. Information about the bandwidth and initial frequency of symptoms are important to limit the frequency passed on filtering *band-pass* filters [10]. Furthermore, the spatial area analysis was carried out to determine the angle of back azimuth and the incidence of the volcanic earthquake. The procedure of this research can be seen in Figure 1.

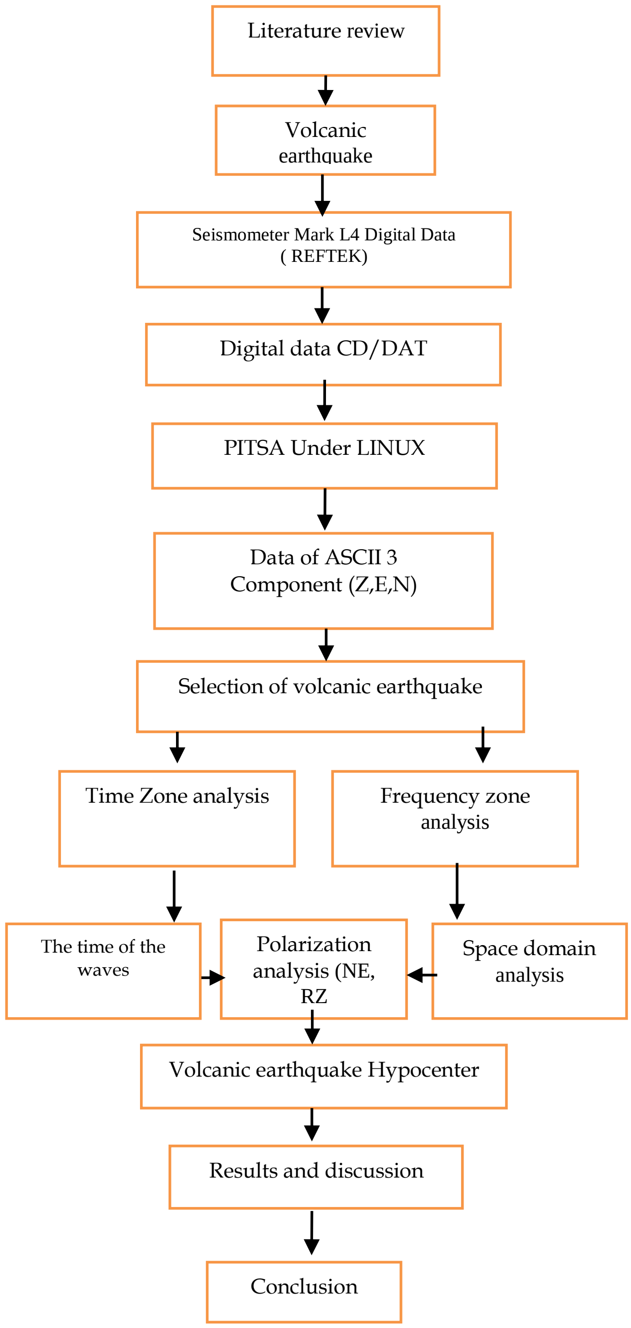

Figure 1: Research procedure

This analysis is used to determine the hypocenter and epicenter of the volcanic earthquake. If the arrow of *back azimuth* and angle of incidence of the volcanic earthquake are extended, they will find the hypocenter and epicenter of the volcanic earthquake. If this projection line goes to the earth's surface, it will find the volcanic earthquake's hypocenter.

Result and Discussion

Volcanic earthquake recording data from the seismometer consists of 3 directional components, which are vertical (Z), North-South (N), and East-West

(E) directions. This data comes from 3 stations, namely Klatakan (KLT), Kendal (KEN), Selo (SEL), on the ridge of Mount Merapi. The position and data of the seismometer can be seen in Figure 2 and Figure 3 below:

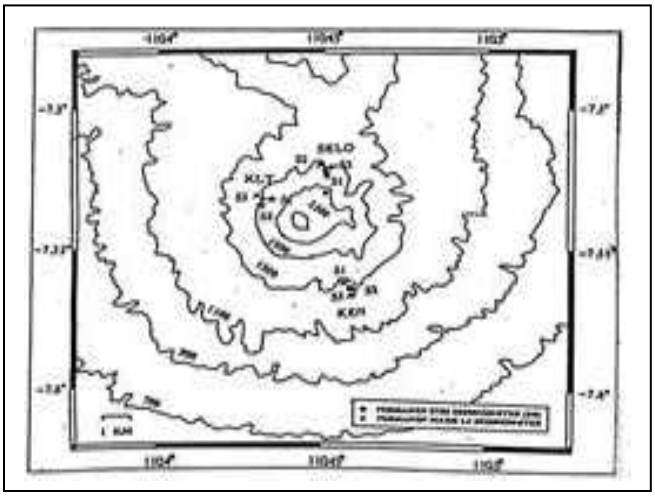

Figure 2: seismometer position

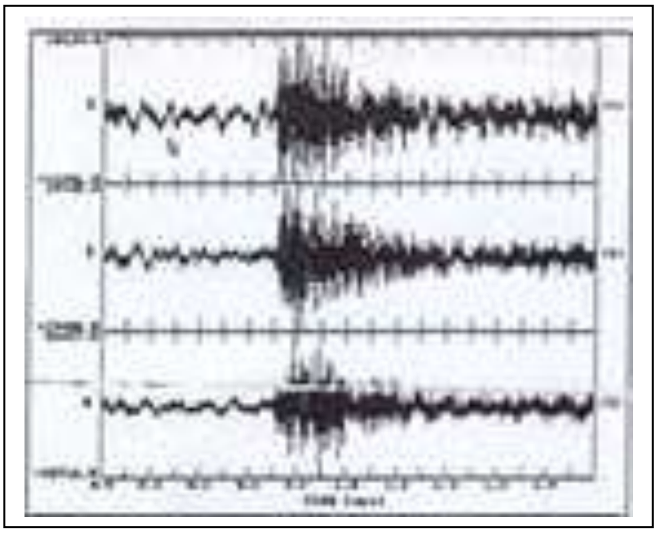

Figure 3: Data of Vulcanic

Data were analyzed in 3 regions, which are time zone, frequency area, and spatial area. Analysis of the time zone can be done when the volcanic earthquake arrives. The frequency region has information about the source frequency and frequency bandwidth to be passed, and the volcanic earthquake hypocenter determines the region of the space. The analysis results showed that a source frequency of 6 Hz and a bandwidth of 0.1 Hz. The analysis results in the region of time and frequency using the PITSA under the LINUX program can be seen in figure 4 and figure 5.

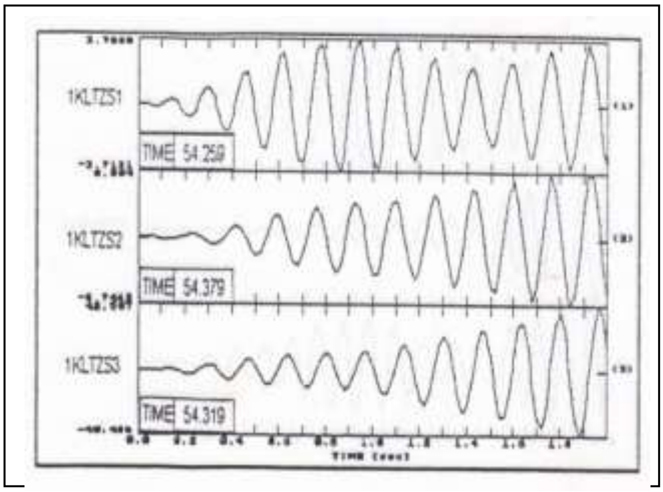

Figure 4: Result of analysis from time zone and frequency region

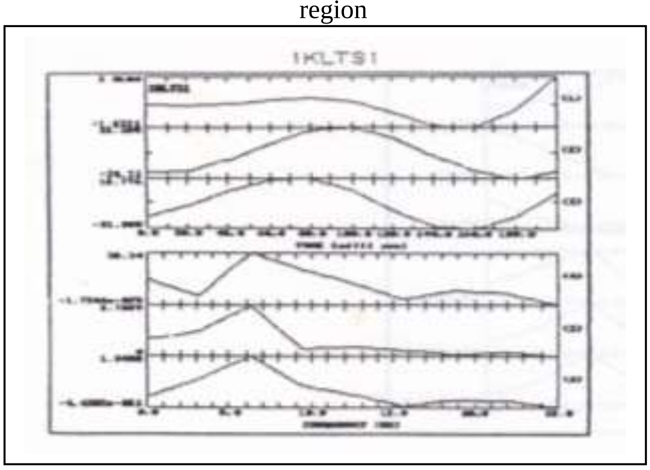

Figure 5: Result of analysis from frequency zone

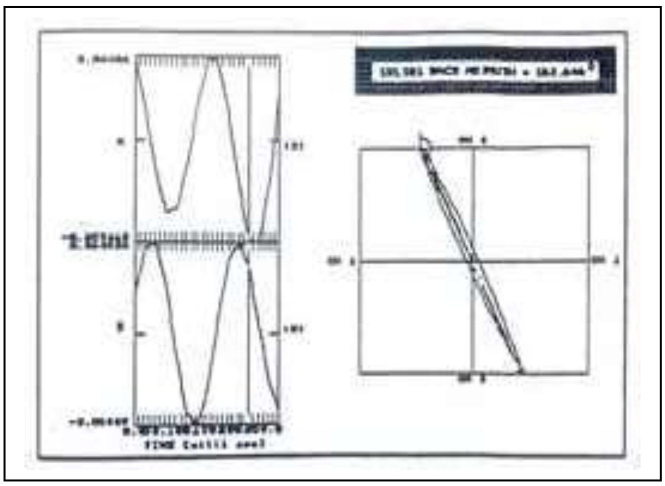

Figure 6: Result of analysis Polarization

The results of this polarization analysis are compared with the Stationary coordinate as Figure 7.

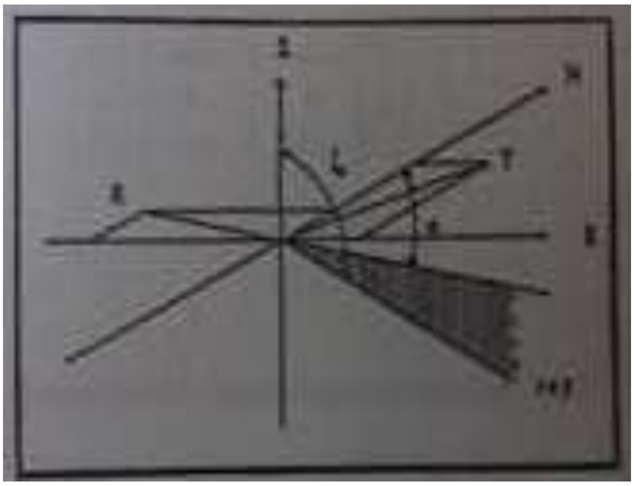

Figure 7: Stationary Coordinate

The *back azimuth* prices of each seismometer are depicted on the Merapi volcano contour map. The most intersection point in the seismometer's reverse azimuth is considered the volcanic earthquake (figure 6). Calculation of the horizontal distance between the seismometer and the epicenter is carried out directly on the map correlated with the map scale. Determining the source of volcanic earthquakes' depth is done by plotting the incident angle by first drawing the epicenter extension line to depth. The intersection of the most lines indicated the depth of the volcanic earthquake's source with its errata. The results of this plotting can be seen in Figure 9 and Figure 10. Based on the epicenter plotting results and the volcanic earthquake's hypocenter, the researcher obtained the distribution of volcanic earthquakes on Mount Merapi, as in Figure 8.

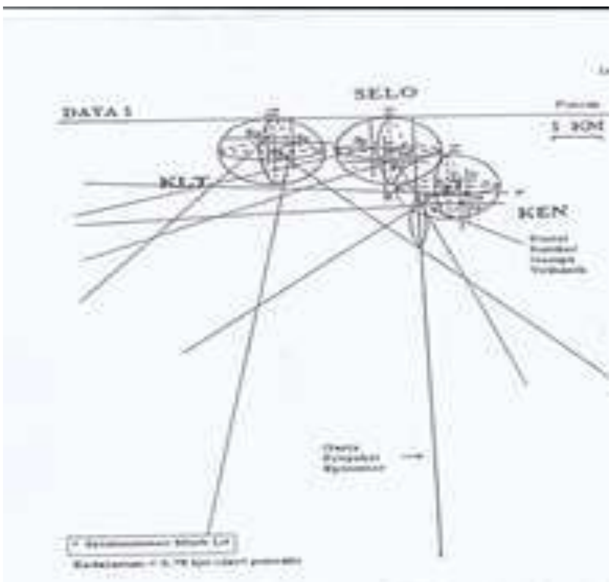

Figure 8: Plotting the incidence angle of the wave

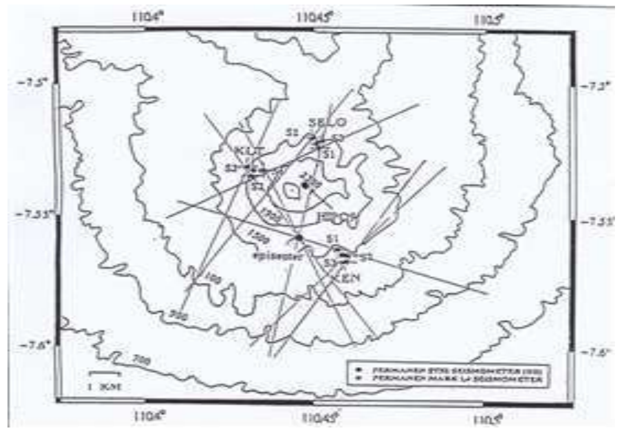

Figure 9: plotting the back azimuth angle of the wave

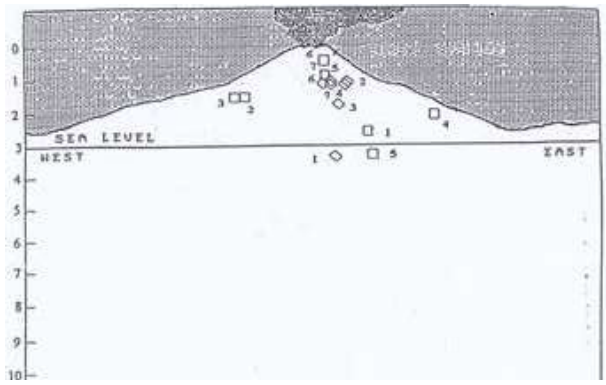

Figure 9: the distribution of volcanic earthquakes on Mount Merapi

The distribution of volcanic earthquakes is obtained through the internal model of the volcano [12]. In his study, Fadeli [12] made a model of pipes and magma bags based on volcanic tremor analysis. Wahyudi [13] also discovered a model of the Mount Merapi magma using the gravity method. Kirbani [14] proposed that the subsurface structure of Mount Merapi, as shown in Figure 10.

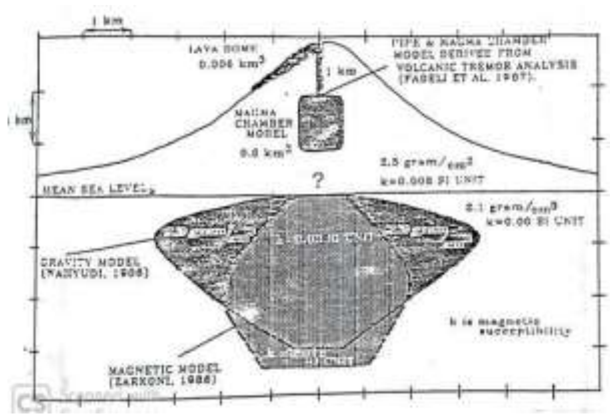

Figure 10: Subsurface structure of Mount Merapi (Kirbani, 1988)

Conclusion

Based on the results and discussions of plotting above, it can be concluded that the epicenter position and depth of the volcanic earthquake sources by using polarization analysis tend to spread with varying depths from 670 m to 3250 m from the peak of Mount Merapi.

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